Pulse-Tube Refrigeration for Spacecraft and Commercial Applications

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A pulse-tube refrigerator breadboard unit has been built and tested by Dean Applied Technology Company under a phase II Small Business Innovation Research contract (NAS8–39917). Pulse-tube refrigeration, offering a viable alternative to chlorofluorocarbon/hydrochlorofluorocarbon systems, uses helium as the working fluid and is, therefore, nontoxic to humans and totally harmless to the environment. Microgravity-compatible because they require no boiling or condensing zero-gravity heat transfer, pulse-tube refrigerators can be operated over a wide range of temperatures and are directly applicable to numerous space and commercial refrigeration requirements. These include food refrigerator/freezers, laboratory freezers, freeze dryers, and computer cooling, as well as detector and electronics cooling. The pulse-tube refrigerator that was built operates in a temperature range required for food freezers, where pulse-tube refrigerators have never been applied before. This technology is applicable to the space shuttle, the *International Space Station* and Mir, and future NASA missions.

The Pulse-Tube Refrigeration Cycle is a relative newcomer compared to other refrigeration cycles. In 1963, Professor Gifford of Syracuse University and his graduate student, R. Longsworth, noticed that blanked-off plumbing lines connected to gas compressors became hot at the closed end.[1]

In 1982, Dr. Pete Kittle of NASA's Ames Research Center joined with Dr. Ray Radebaugh of the National Institute of Standards and Technology and began developing pulse tubes. In 1983, they made a breakthrough when, without adding any moving components, they were able to improve the efficiency of the pulse-tube refrigerator by increasing the phase shift between the pressure and the mass flow. This improvement—done by connecting an orifice and a reservoir to the hot end of the pulse tube—became the standard pulse-tube refrigerator configuration known as the orifice pulse tube. Single-stage orifice pulse-tube refrigerators (fig. 99) have reached 30 Kelvin, while a three-stage orifice pulse tube has reached 3.6 Kelvin.

One of the major motivations for development of this technology is as an alternative to the current space station food refrigerator/freezer technology. The current technology is thermo-electric, which is very reliable and has virtually no vibration. However, thermo-electric refrigerators are also very inefficient. In fact, as the temperature lift increases, the power consumption for thermo-electric refrigerators increases exponentially. Pulse-tube refrigeration offers high reliability, low vibration, and much higher efficiencies. Electrical power consumption on the space station is extremely critical; therefore, development of alternative technologies such as pulse-tube refrigeration technology is necessary.

The pulse-tube refrigerator demonstration unit built by Dean Applied Technology Company, Inc. has been designed and built to operate at a temperature range and load level needed for typical food freezers and laboratory freezers. As far as is known, this is the first time that such a refrigerator has been applied to this temperature range. Details of the design are given in reference 2.

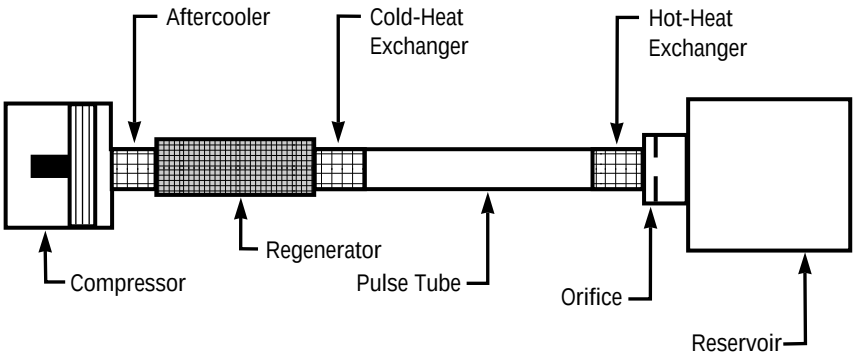

FIGURE 99.—Single-stage orifice pulse-tube refrigerator.

After design and fabrication, this pulse-tube refrigeration development model was subjected to numerous tests. A temperature of – 45 °C (–50 °F) has been reached, which is well below the temperature required for food freezers. The next step will be to improve efficiency, reduce cost, and gain experience in integration with freezer cabinets and power sources.

Although the development unit was built primarily for zero-gravity application, it has numerous possibilities as a commercial technology, including use in home food refrigerator/freezers, laboratory freezers, medical/cryobiology applications, cooling of electronics, and superconductivity research.

[1]Kittel, P. 1994. A Short History of Pulse-Tube Refrigerators. Eighth International Cryocooler Conference.

[2]Dean, W.G., and Westra, D.G. October 24–26, 1995. Pulse-Tube Refrigeration for Spacecraft and Commercial Applications. Presented at NASA Technology 2005 Conference, Chicago, Illinois.

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